SolarPACES

Heliostat Performance Testing Guideline
- Status

Marc Röger

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01.10.2018

Overview

1 Objective of Guideline

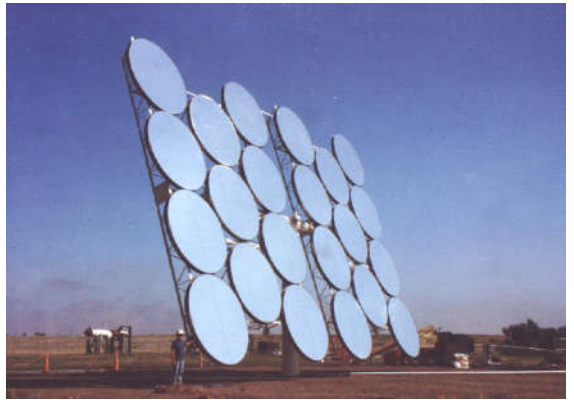
2 Status

3 Overview of Guideline

4 Updates to version 0.95 (from Sept. 2017) to 0.992 (actual)

1 Objective of Guideline

Objective of Guideline



- Enable comparison of different heliostats on an objective, scientific, but practical level
- Homogenize content of test certificates of different qualification centers
- Facilitate bankability of heliostats

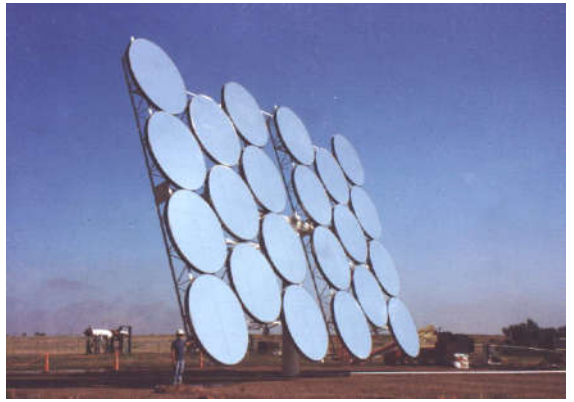
→ **The guideline for heliostat performance testing** contains an *internationally reviewed*, *concisely defined parameter list* to *describe heliostats* and their *performance*. Additionally, it suggests *measurement techniques* to derive the parameters.

Target Group: Industry, Research/Qualification Centers

2 Status of Guideline

Status: 28.09.18

- Version v0.992
- Includes feedback from experts from CIEMAT, CENER, CSP Services, DLR, CNRS-PROMES, CSIRO, Fraunhofer ISE, KAM, SANDIA, and SBP



Created :

- Template with parameters for qualification centers/service companies
- Example sheet

3 Overview of Guideline

new

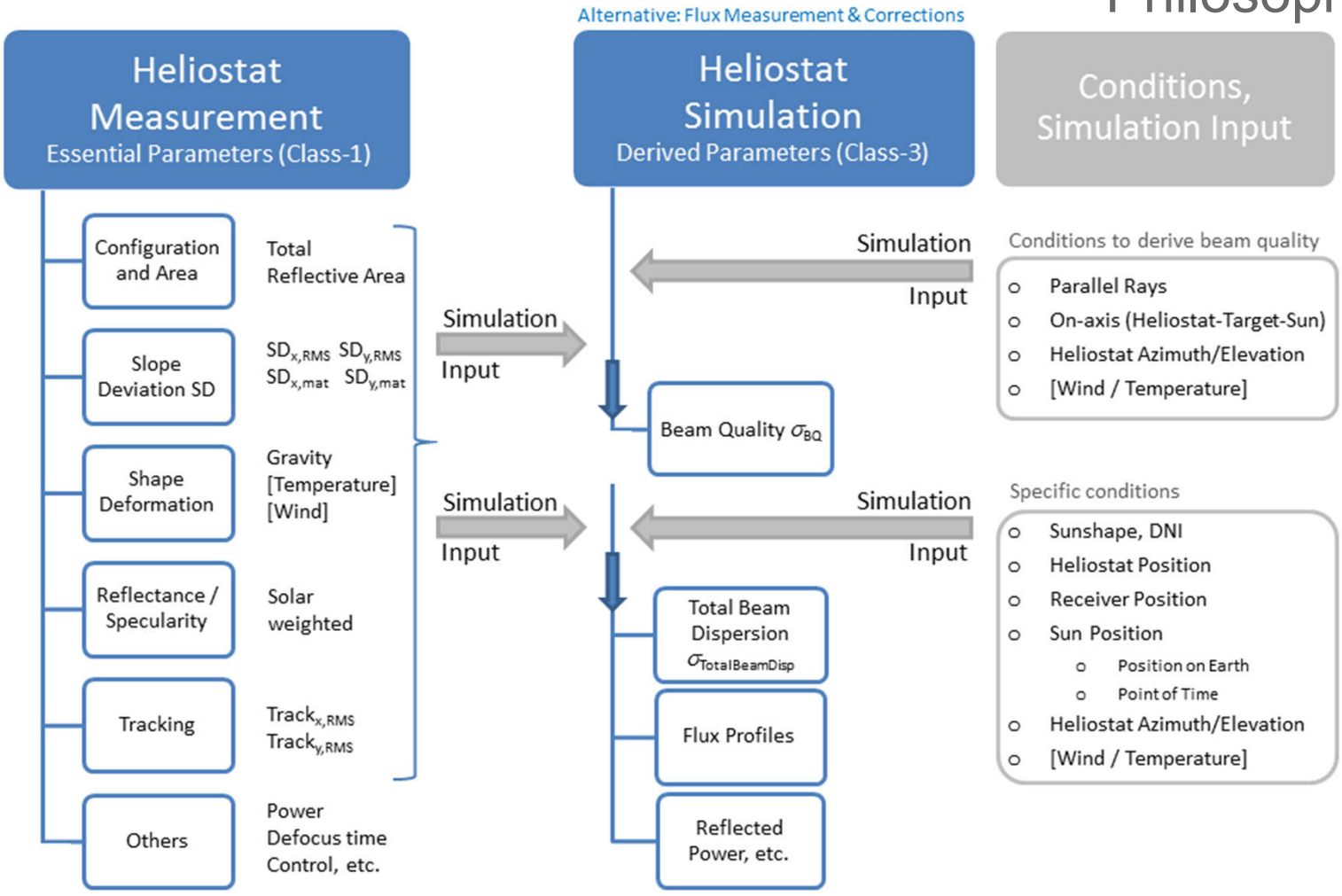
3 Overview of Guideline (Sec. 4: Underlying Philosophy)

The essential parameters (class-1) are *mandatory* to describe heliostat performance according to this guideline. In general, all these parameters must be given for comprehensive description of the heliostat performance..

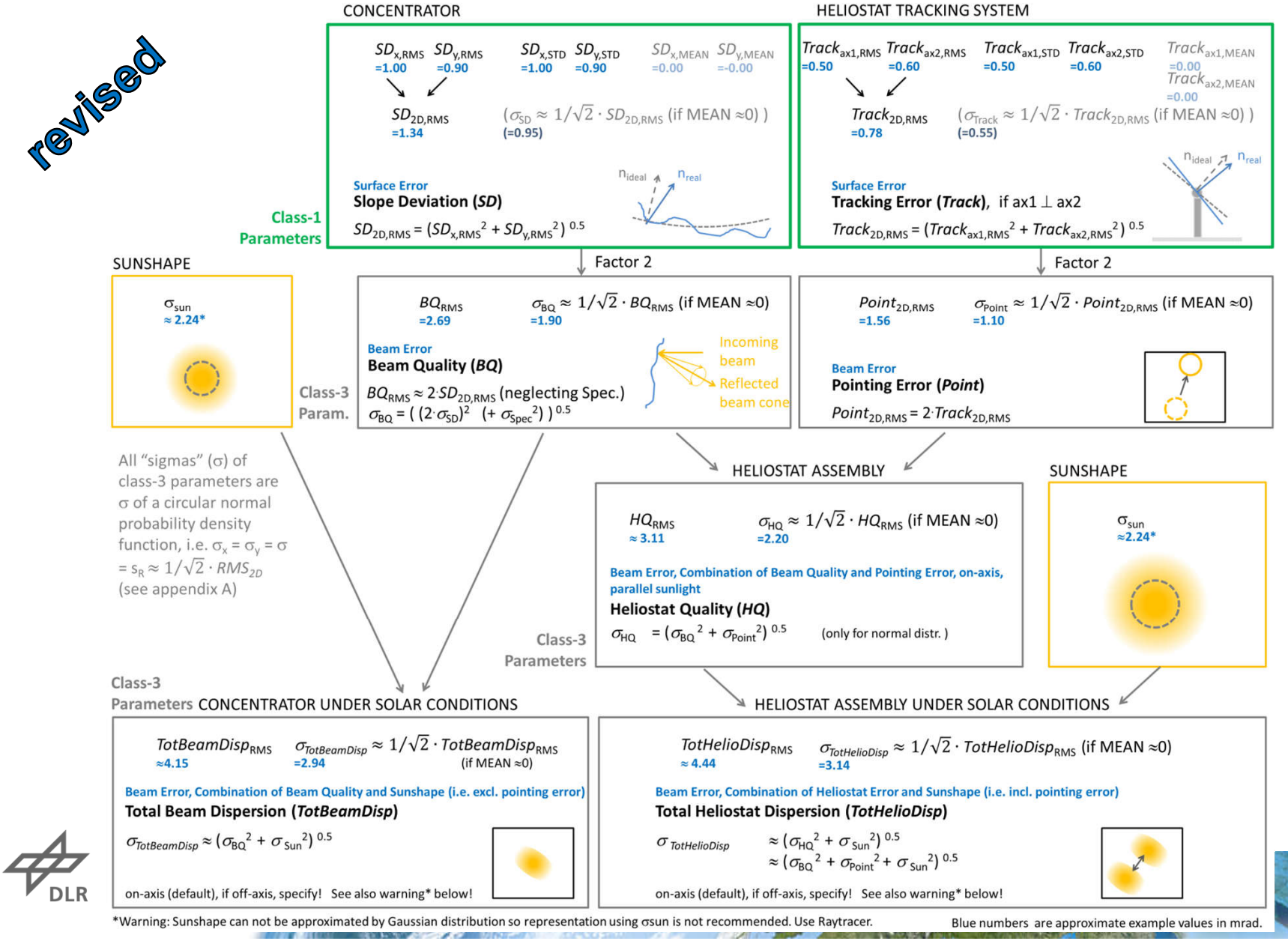
Additional descriptive parameters (class-2) as part of an *extended list* deliver additional, but not essential information. They may be additionally given.

Beam shape parameters (class-3) can be derived from class-1 parameters by *raytracing*, or are *not easily measurable under defined conditions* in industrial practice. Essential parameters should be preferred to define heliostat performance instead. However, beam shape parameters can be additionally used for their *illustrative character*.

3 Overview of Guideline (Sec. 4: Underlying Philosophy)

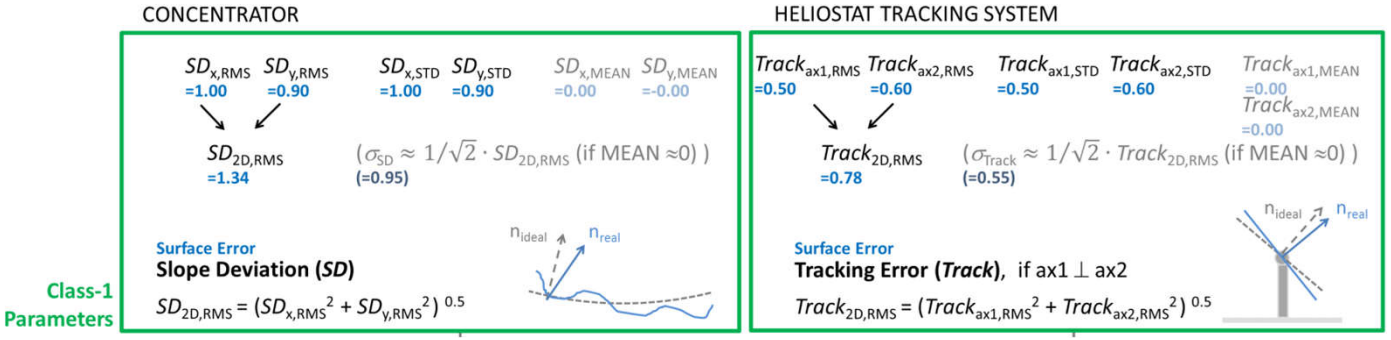


3 Overview of Guideline



3 Overview of Guideline

revised



The good thing is that according the guideline, only the class-1 parameters (*SD* and *Track*) have to be given to define the quality of the heliostat.

The other parameters (*BQ*, *Point*, *HQ*, *TotBeamDisp*, *TotHelioDisp*) are class-3 parameters and are not essential.

4 Updates: Performance Parameter List

4 Updates: Performance Parameter List

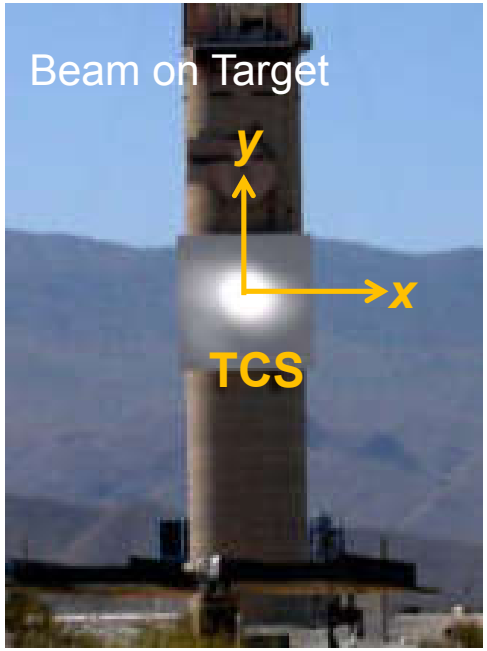
revised

Tracking Accuracy

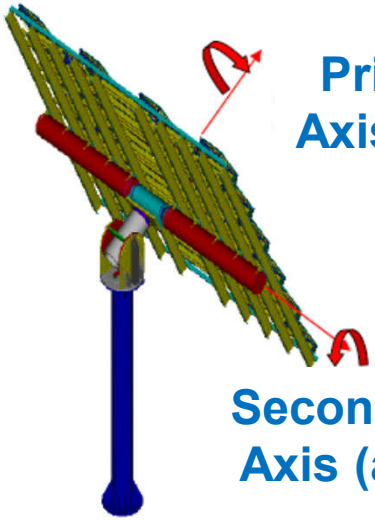
Measure → Pointing Accuracy in TCS → Calculate → Tracking Accuracy around axes

Tracking.PointingAccuracy.Point_x
Tracking.PointingAccuracy.Point_y
(class-3 param.)

Tracking.TrackingAccuracy.Track_ax1
Tracking.TrackingAccuracy.Track_ax2
(class-1 param.)



Target Coordinate System

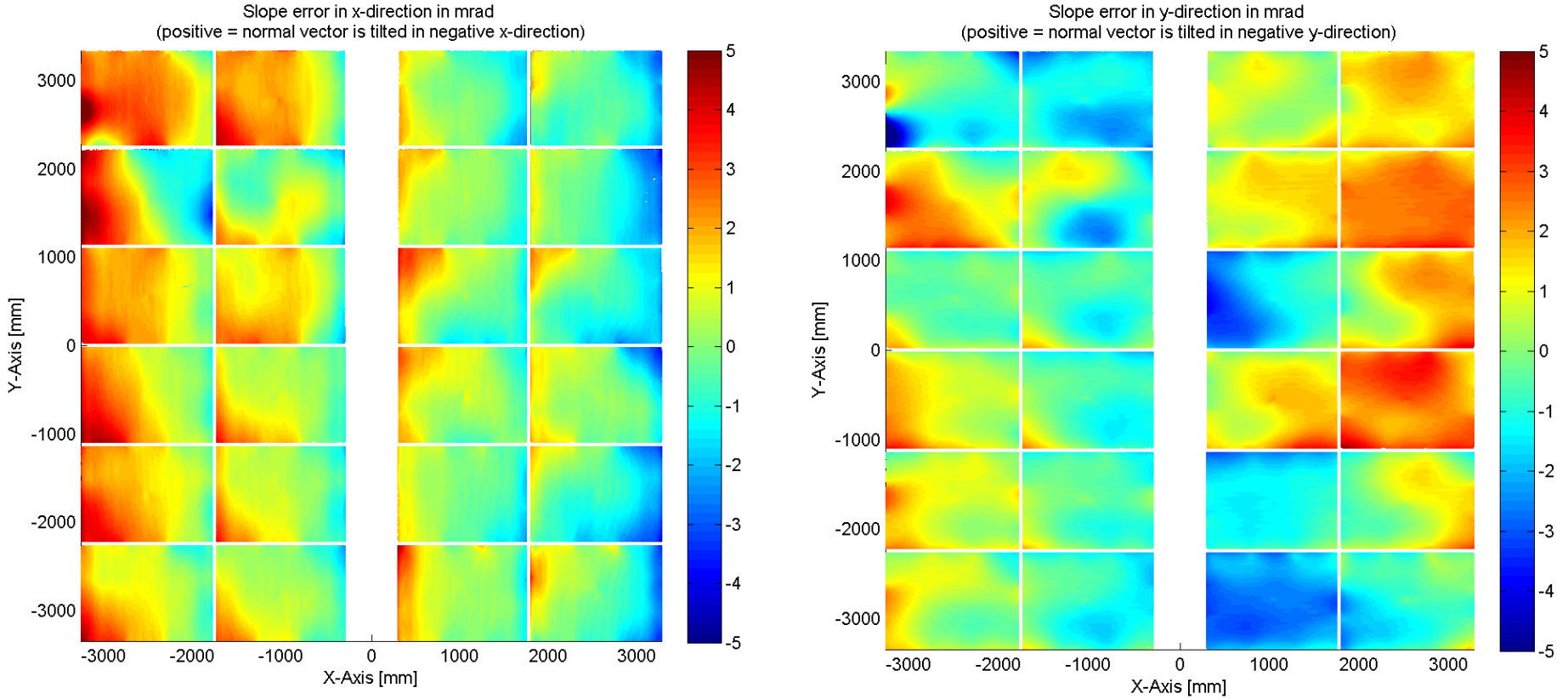


e.g. target-aligned heliostat

Around tracking axes

4 Updates: Performance Parameter List
How significant are the statistical values ?

Slope Deviation SD (1)

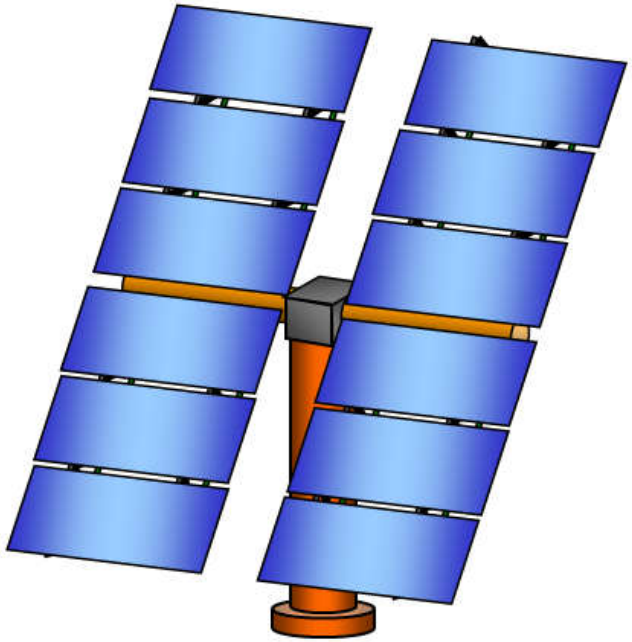


$SD_{x,mat}$ → *RMS, MEAN,STD* ← $SD_{y,mat}$

4 Updates: Performance Parameter List
How significant are the statistical values ?

revised

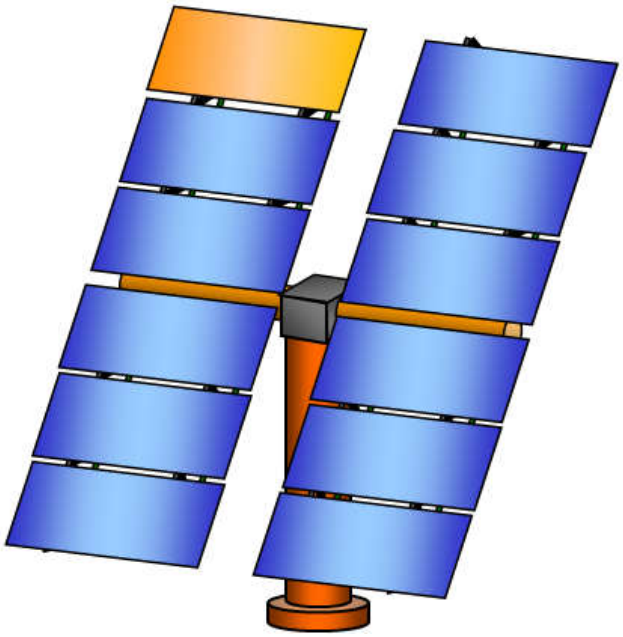
Slope Deviation SD (2)



$SD_{x/y} = SD_{x/y}^{*} = SD_{x/y}^{HighFraction}$

$SD_{x:}$	RMS:1.76	MEAN:0.19	STD:1.76 (100%)
SD_{x}^{*} :	RMS:1.76	MEAN:0.19	STD:1.76 (100%)
$SD_{x}^{HighFraction}$	RMS: -	MEAN -	STD:- (0%)

Misaligned mirror facet



$SD_{x/y} \neq SD_{x/y}^{*} \neq SD_{x/y}^{HighFraction}$

$SD_{x:}$	RMS:1.76	MEAN:0.19	STD:1.76 (100%)
SD_{x}^{*} :	RMS:1.10	MEAN:0.00	STD:1.11 (98%)
$SD_{x}^{HighFraction}$	RMS:9.75	MEAN:9.75	STD:0.35 (2%)

4 Updates: Performance Parameter List
How significant are the statistical values ?

revised

Slope Deviation SD (3)

SD_x: RMS, MEAN and STD for whole measured surface (=100%)

SD_x^*: RMS, MEAN and STD for region of measured surface values *lower than* 3x $SD_{x,RMS}$.
In parentheses give the share of region of measured surface values *lower than* 3x $SD_{x,RMS}$ with respect to whole measured region

$SD_x^{HighFraction}$: RMS, MEAN and STD for region of measured surface values *higher than* 3x $SD_{x,RMS}$.
In parentheses give the share of region of measured surface values *higher than* 3x $SD_{x,RMS}$ with respect to whole measured region

Use ROBUST least squares optimization for the orientation of measured data to the nominal geometry

4 Updates: Performance Parameter List

revised

Equation for Slope Deviation

Deformation equation was revised

$$SD^{sum}_{x/y,mat}(az, el, v_{wind}, T) = SD_{x/y,mat}\Big|_{\substack{el,ref \\ az,ref \\ v,wind,ref \approx 0 \\ T,ref}} + \Delta SD^{grav}_{x/y,mat}\Big|_{\substack{(el-el,ref) \\ (az-az,ref)}}$$

[mrad]

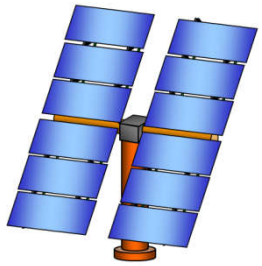
$$+ \Delta SD^{wind}_{x/y,mat}\Big|_{v,wind}$$

[mrad]

$$+ \left(\Delta SD^{temp}_{x/y,mat}/\Delta T\right) \cdot \left(T - T_{ref}\right)$$

[mrad/K]

for practical reasons: linear gradient



4 Updates: Measurement Descriptions

4 Updates: Measurement Descriptions

revised

Several descriptions to derive performance parameters were revised and more details added:

e.g. tracking measurements,

e.g. measure emergency defocus times, etc.

4 Updates: Reporting

4 Updates: Reporting, page 1

NEW

- Template with parameters for qualification centers/service companies
- Example sheet, TOTAL: 59 parameters

revised

HELIOSTAT PERFORMANCE TEST	
Photo or simplified scheme of general heliostat configuration	
Heliostat manufacturer name	HeliostatFactory
Name of heliostat model	Superb
Serial number(s) or other identifier(s)	P4
Total number of heliostats investigated	1
Name and address of testing laboratory	R&D Testing Center, Street Name, City, Country
Testing location	Plataforma Solar de Almería, 04200 Tabernas, Spain
Date of testing period	30.04.17 - 30.07.17
Date of erection of heliostat	01.04.17
Reference to guideline version	SolarPACES Heliostat Performance Guideline v0.99 from 21.08.18
Report format	This report and data CD
Date, signature and stamp of independant qualification organization/company	

4 Updates: Reporting, page 2

revised

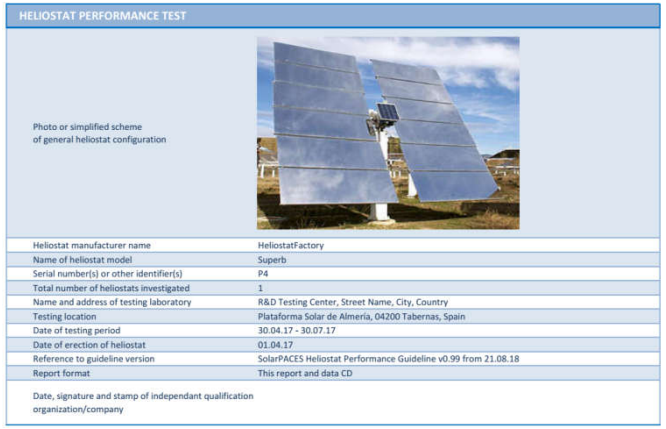
n	Full Parameter Name (Symbol)	Value	Unit	Meas.Techn.	Measurement Report
1	HelioConfig.General.Type	T-shape	-	-	
2	HelioConfig.Conc.Outline	rectang.	-	-	
3	HelioConfig.Conc.Dimension	[6.6; 6.7]	m	Laser dist.meter	Hel_Main.pdf
4	HelioConfig.Conc.ReflectiveArea	40.1	m^2	Laser dist.meter	Hel_Main.pdf
5	HelioConfig.Panel.Outline	rectang.	-	-	
6	HelioConfig.Panel.Dimension	[3.0; 1.1]	m	Laser dist.meter	Hel_Main.pdf
7	HelioConfig.Panel.Number	[2; 6]	-	-	
8	HelioConfig.Panel.Type	glass mirror panels	-	-	
9	HelioConfig.Panel.Material	silver coated glass	-	-	
10	HelioConfig.Axes.Alignment	[az. axis vert.; el. axis horiz.]	-	-	
11	HelioConfig.Axes.HeightOfSecondaryAxis	2.14	m	Laser dist.meter	Hel_Main.pdf
12	HelioConfig.Axes.DistanceConcToSecondaryAxis	0.1	m	Tape meter	Hel_Main.pdf
13	Optics.Panel.CurvatureMounted	flat	-	-	
14	Optics.Panel.CurvatureMethod	tension-less	-	-	
15	Optics.Conc.NominalShape	parabolic	-	-	
16	Optics.Conc.NominalShapeNumericValue	[55] or [25;1500] or matrices	m	-	
17	Optics.Conc.HelioRefOrientationTemp	[az=0°; el=30°; T=20°C]	-	Inclinometer	Hel_Shape.pdf
18	Optics.Conc.SD_SamplingRate	1000	values/m2	-	Hel_Shape.pdf
19	Optics.Conc.SD_ShareEvalSurf	97	%	-	Hel_Shape.pdf
20	Optics.Conc.SD_2D	RMS: 2.06 (100%)	mrad	Deflectometry	Hel_Shape.pdf
21	Optics.Conc.SD_2D*	RMS: 1.54 (98%)	mrad	Deflectometry	Hel_Shape.pdf
22	Optics.Conc.SD_2DHighFraction	RMS: 9.83 (2%)	mrad	Deflectometry	Hel_Shape.pdf
23	Optics.Conc.SDx /SDrad	RMS: 1.76 MEAN: 0.19 STD: 1.76 (100%)	mrad	Deflectometry	Hel_Shape.pdf
24	Optics.Conc.SDx* /SDrad*	RMS: 1.10 MEAN: 0.00 STD: 1.11 (98%)	mrad	Deflectometry	Hel_Shape.pdf
25	Optics.Conc.SDxHighFraction/ SDradHighFraction	RMS: 9.75 MEAN: 9.75 STD: 0.35 (2%)	mrad	Deflectometry	Hel_Shape.pdf
26	Optics.Conc.SDy /SDtan	RMS: 1.08 MEAN: -0.03 STD: 1.09 (100%)	mrad	Deflectometry	Hel_Shape.pdf
27	Optics.Conc.SDy* /SDtan*	RMS: 1.08 MEAN: -0.03 STD: 1.09 (100%)	mrad	Deflectometry	Hel_Shape.pdf
28	Optics.Conc.SDyHighFraction / SDtanHighFraction	RMS: - MEAN: - STD: - (0%)	mrad	Deflectometry	Hel_Shape.pdf
29	Optics.Conc.SD_NonGaussianDistr	No	-	Deflectometry	Hel_Shape.pdf

4 Updates: Reporting, page 3

revised

30	Optics.Conc.SDmat	2 matrices, see CD	mrad	Deflectometr.	Hel_Shape.pdf +CD
31	Optics.Conc.SD_NonResolvedStruct	No	-	Deflect.+Visual	Hel_Shape.pdf
32	Optics.Conc.SD_DiffBetwRegions	No	-	Deflect.+Visual	Hel_Shape.pdf
33	Optics.Conc.DefGravity_deltaSDmat	5 x 2 matrices and elevation vector, see CD	mrad	Photogrammetr.	Hel_Shape.pdf +CD
34	Optics.Conc.DefTemp_deltaSDmat_perK	2 matrices, see CD	mrad/K	Photogrammetr.	Hel_Shape.pdf +CD
35	Optics.Reflectance.SolarWeightedSpecular2.3	92.5	%	Reflectom.	Refl_Report.pdf
36	Optics.Focus.Variability	fix focal length	-	-	
37	Tracking.Axes.Concept	[el.motor/gear dr.; el.motor/gear dr.]	-	-	
38	Tracking.Axes.Control	[closed loop; cl. loop]	-	-	
39	Tracking.Axes.MinMaxRangeAxis1	[-80; 80]	°	Inclinometer	Hel_Main.pdf
40	Tracking.Axes.MinMaxRangeAxis2	[-180; 180]	°	Inclinometer	Hel_Main.pdf
41	Tracking.Accuracy.Track_2D	RMS: 1.06	mrad	Beam on target	Hel_Track.pdf
42	Tracking.Accuracy.Track_ax1	RMS: 0.75 MEAN: 0.01 STD: 0.75	mrad	Beam on target	Hel_Track.pdf
43	Tracking.Accuracy.Track_ax2	RMS: 0.75 MEAN: 0.00 STD: 0.75	mrad	Beam on target	Hel_Track.pdf
44	Tracking.Accuracy.TrackingTimeCorrelationAx1Ax2	[0.1; -0.2]	-	Beam on target	Hel_Track.pdf
45	Tracking.Accuracy.TrackingAx1Ax2Correlation	0.2	-	Beam on target	Hel_Track.pdf
46	Tracking.Safety.EmergDefocusTime	[15; 20]	s	Inclinom.+Clock	Hel_Track.pdf
47	Tracking.Safety.StowPosition	face down, -10°	- /°	Inclinometer	Hel_Track.pdf
48	Control.Instrumentation.Communication	wired, RS485	-	-	
49	Control.Power.SupplyType	electrical	-	-	
50	Control.Power.InputType	230 V	-	-	
51	Control.Power.InputPowerEmergDefocus	[397; 450] @ 21°C	W	Power meter	Hel_Power.pdf
52	Control.Power.InputPowerColdStart	[189; 200] @ 15°C	W	Power meter	Hel_Power.pdf
53	LimitsTol.WindSpeed.NormalOperation	8	m/s	-	
54	LimitsTol.WindSpeed.ReducedOperation	20	m/s	-	
55	LimitsTol.WindSpeed.GustSurvival	40	m/s	-	
56	LimitsTol..OperatingTemp	[-20;50]	°C	-	
57	LimitsTol.Lifetime.Overall	25	years	-	
58	Cost..Total	1'900 (Morocco)	€	-	
59	Cost..SpecificWithoutFoundation	120	€/m²	-	

4 Updates: Reporting, Detailed reports



HELIOSTAT PERFORMANCE TEST

Photo or simplified scheme of general heliostat configuration

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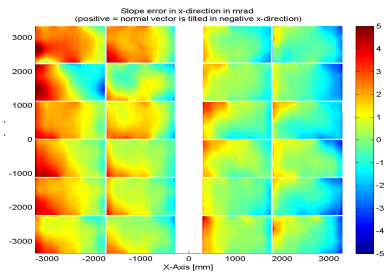
Reference to guideline version	SolarPACES Heliostat Performance Guideline v0.99 from 21.08.18
Report format	This report and data CD

Date, signature and stamp of independant qualification organization/company

Results in:

- Main test report in tabular form with links to appended data, measurement report pdfs, graphs



Measurement Report

Slope Deviation Measurement

Further information appended in:

- Data format (in case of matrices, e.g.)
- Graphical form (in case of matrices, vectors, e.g.)
- Detailed measurement reports

DLR

4 Updates: Appendix A

new

4 Updates: new Appendix A
How to Use Concentrator Optics Parameters in Raytracing Software

new

Table A-1: Probability density functions used in raytracing software for slope deviations

Statistical distribution	Parameter	Probability density function	Software Example
None (1)	$SD_{x,mat}$, $SD_{y,mat}$	-	STRAL SPRAY
"Elliptic" normal (bivariate)	σ_x, σ_y $=\sigma_{SDx}$, σ_{SDy}	$P(x,y) = \frac{1}{2\pi\sigma_x\sigma_y} e^{-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2}\right)}$	
"Circular" normal	σ	$P(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{1}{2}\left(\frac{x^2+y^2}{\sigma^2}\right)}$	
or (2)	The "circular" normal distribution can be also expressed as Rayleigh distribution (generated by the Box-Muller transform for example)		STRAL SPRAY MIRVAL HFLCAL
Rayleigh distribution	s_R	$P(r) = \frac{r}{s_R^2} e^{-\frac{r^2}{2s_R^2}}$ with $r = \sqrt{x^2+y^2}$ and $s_R = \sigma$	

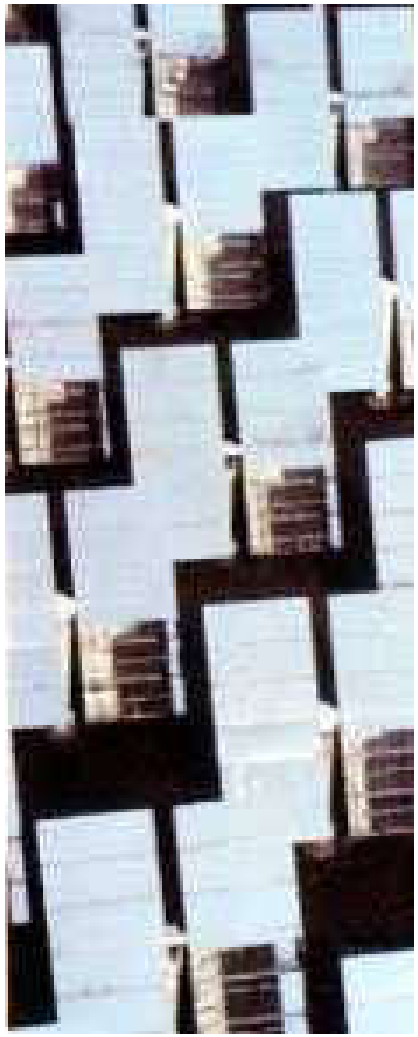
x,y in Heliostat Coordinate System HCS

4 Updates: new Appendix A
How to Use Concentrator Optics Parameters in Raytracing Software

new

Table A-3: Statistical raytracer inputs generated from measurement parameters of the guideline

Ref.	Param.	Software & Statistical distribution	Raytracer input	Example in mrad
1	Slope	STRAL, SPRAY None	Directly use matrix information $SD_{x,mat}$, $SD_{y,mat}$	x[m,n] y[m,n]
2	Slope	STRAL SPRAY MIRVAL HFLCAL "Circular" normal, or Rayleigh	if local value matrixes for *x* and *y* are given: using formula of next line with $SD_{x,STD} = STD\ (SD_{x,mat})$ $SD_{y,STD} = STD\ (SD_{y,mat})$	0.50 0.60
			if statistical values for *x* and *y* are given: $\text{"}\sigma\text{"} = s_R = 1/\sqrt{2} \cdot \sqrt{SD_{x,STD}^2 + SD_{y,STD}^2}$ $\approx 1/\sqrt{2} \cdot \sqrt{SD_{x,RMS}^2 + SD_{y,RMS}^2}$ *	$1/\sqrt{2} \cdot \sqrt{0.50^2 + 0.60^2}$ =0.55
			if only 2D statistical values are given: $\text{"}\sigma\text{"} = s_R \approx 1/\sqrt{2} \cdot SD_{2D,RMS}$ *	$1/\sqrt{2} \cdot 0.78$ =0.55



THANK YOU for your attention
THANKS to all contributing persons

The actual working version of the guideline can be ordered per email from marc.roeger@dlr.de

Marc Röger, marc.roeger@dlr.de
DLR, Qualification, Systems

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